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DESIGN, PERFORMANCE, AND INSTALLATION OF A PRESS-LAM BASEMENT B--ETC(U)
1978 J A YOUNGQUIST, D S GROMALA
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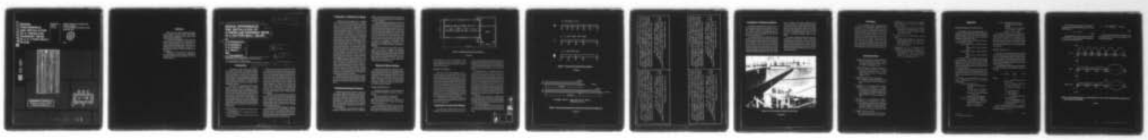

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DESIGN, PERFORMANCE, AND INSTALLATION OF A PRESS-LAM BASEMENT BEAM IN A FACTORY-BUILT HOUSE

RESEARCH PAPER
FPL 316

FOREST PRODUCTS LABORATORY
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
MADISON, WIS.

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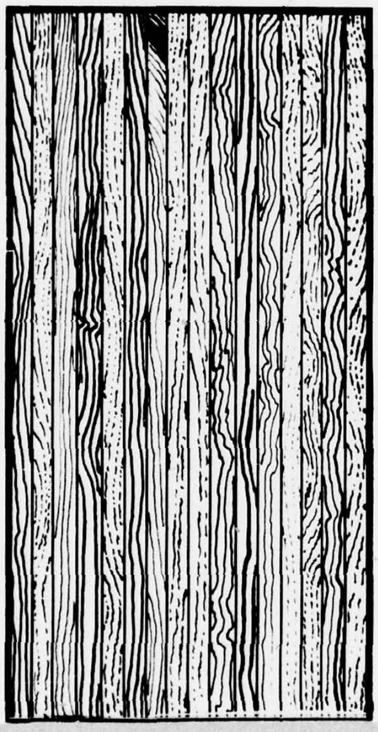
1978



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Abstract

Press-Lam and other parallel-laminated-veneer products exhibit distinct advantages when utilized in applications that require well-defined material properties.

A Press-Lam basement beam was designed and manufactured for a model prebuilt house. Design stresses were determined in conjunction with another Press-Lam study. The finished beam was installed by a regular construction crew using no special equipment or techniques.

Performance of this beam is expected to be comparable to other design alternatives, and to exceed design requirements for the life of the structure.

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9 Forest service research papers

DESIGN, PERFORMANCE, AND INSTALLATION OF A PRESS-LAM BASEMENT BEAM IN A FACTORY-BUILT HOUSE[1] .

By

10 J. A. YOUNGQUIST,
D. S. GROMALA,
R. W. JOKERST,
R. C. MOODY,
[redacted]
J. L. TSCHERNITZ

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Forest Products Laboratory,[2] Forest Service
U.S. Department of Agriculture

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Introduction

As supplies of large, high-quality sawtimber decline, additional raw material supplies must be sought for the manufacture of structural-size timbers for items such as basement beams. Small or low-grade logs can fill that demand if they can be processed into engineered wood products. Press-Lam, a process developed at the Forest Products Laboratory (FPL), offers that potential.

Press-Lam is a parallel-laminated-veneer product, made by peeling logs on a veneer lathe, drying the veneer in a heated press, applying an adhesive, layering and pressing again into a continuous sheet of laminated wood. Research at FPL has examined the effects of veneer peeling, press drying, and laminating on product performance (*4*)[3]. Other aspects of PLV research have been explored by the USDA Forest Service's Southern Forest Experiment Station and by the Canadian Forest Products Laboratories.

Because the physical dimensions of the continuous sheets are limited only by production equipment, sheets can be ripped and cross-cut to meet desired end-product requirements. Extensive test programs at FPL on experimentally produced parallel-laminated veneer have established that the mechanical properties of this product can be closely controlled. Markets for which PLV may be well suited include mobile home center beams and truss chords, components for manufactured housing, door rails and stiles, tension laminations for glulam beams, and roof decking support systems.

The beam project described in this report covers one of four chosen FPL demonstration uses of parallel-laminated veneer for structural and/or specialty products. Other reported demonstration uses include railroad ties (*7*), electrical distribution crossarms (*8*), and bridge timbers and decking (*9*).

To demonstrate the feasibility of incorporating Press-Lam into a house design, the FPL entered into a cooperative agreement with Wausau Homes, Incorporated, of Wausau, Wis., to supply a Press-Lam basement beam for installation and use in a prebuilt house.

[1] Research conducted in cooperation with Wausau Homes, Inc., Wausau, Wis.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to literature cited at the end of this report.

Preparation of Material for Beam

Peelable Coast Douglas-fir No. 2 sawlogs were shipped to the Forest Products Laboratory, cut to 52-inch bolt lengths, and rotary peeled on a 4-foot lathe to a thickness of 0.42 inch. This veneer was then clipped to 21-inch widths and press dried at 375° F at 50 psi to an average moisture content of 15 percent. Drying time was either 5.5 minutes or 11 minutes, depending upon whether sapwood or heartwood was being processed. Because the drying press was not in the same building as the laminating equipment used in producing this material, the dried veneer had to be reheated in a conventional veneer drier prior to glue application and lamination. The reheating process reduced the moisture content of the veneer to about 11 percent. This press-dried veneer was then assembled into a continuous sheet of 4-ply step-pressed dimension stock, using a phenol resorcinol adhesive. Veneer placement was staggered in each layer to allow for a 12-inch spacing between adjacent butt joints. The wood was at a minimum temperature of 200° F prior to adhesive application and was laminated using pressures of 150 psi for approximately 6 minutes Dimension material, 1½ by 20 inches in cross-section was then cut to lengths of 21 feet. Both the length and width of these Press-Lam components were constrained by laboratory equipment limitations.

Dimension boards were abrasive planed and cold-laminated into structural-size timbers for use in concurrent studies aimed at determining the properties of large Press-Lam members

Establishing Design Stresses

Eighteen beams were loaded to failure (*9*) in two-point edgewise bending in accordance with ASTM D 198 (*1*). Load and midspan deflection were monitored continuously to failure. Test beams, 4½ inches wide by 20 inches deep, were tested on spans ranging from 17.5 to 19 feet. The average modulus of rupture (MOR) was 5,450 psi, with a coefficient of variation of about 9 percent.

An additional 18 beams were similarly loaded to evaluate their moduli of elasticity (MOE). The average MOE for the 36 beams was 1.7 million psi, with a coefficient of variation of less than 7 percent.

The allowable bending stress was derived by methods outlined in ASTM D 2915 (*2*). The near-minimum strength of the population (5th percentile) was divided by a factor of 2.1 to account for long-term loading and the possibility of accidental overloading of the member. The resultant allowable bending stress was 2,200 psi. This value was then multiplied by factors to account for duration of load (1.15) and size effects (1.06) to arrive at the final allowable stress of 2,680 psi. Deflection calculations were based on the average MOE (1.7 million psi), as specified in the National Design Specification (NDS) (*3*).

Because none of the test beams failed in shear, it is difficult to assess the allowable shear stress for these members. The average shear stress at failure was calculated to be 330 psi. If these beams had failed in shear, the design shear stress would be 130 psi. This value was chosen to represent a conservative estimate of allowable shear stress.

Basement Beam Design

Because the Press-Lam basement beam was to be installed as a minor modification in a factory-designed house, its dimensions were necessarily made compatible with the existing design (fig. 1). The primary constraint from a design standpoint was that the beam depth could not exceed 12 inches. This restriction produced a beam that was less material-efficient than a deeper member.

Design Requirements

The design loadings currently employed by the commercial designers involved in this project are:

Floor Load: 40 psf live; 8 psf dead

Roof Load: 30 psf live; 8 psf dead

Maximum allowable deflection is 1/240th of the span under full load and 1/360th of the span under live load only.

The standard basement beam for this model would be either four glue-nailed 2 by 8's over five intermediate supports (fig. 2a), or a steel beam, 8 inches deep, over three interme-

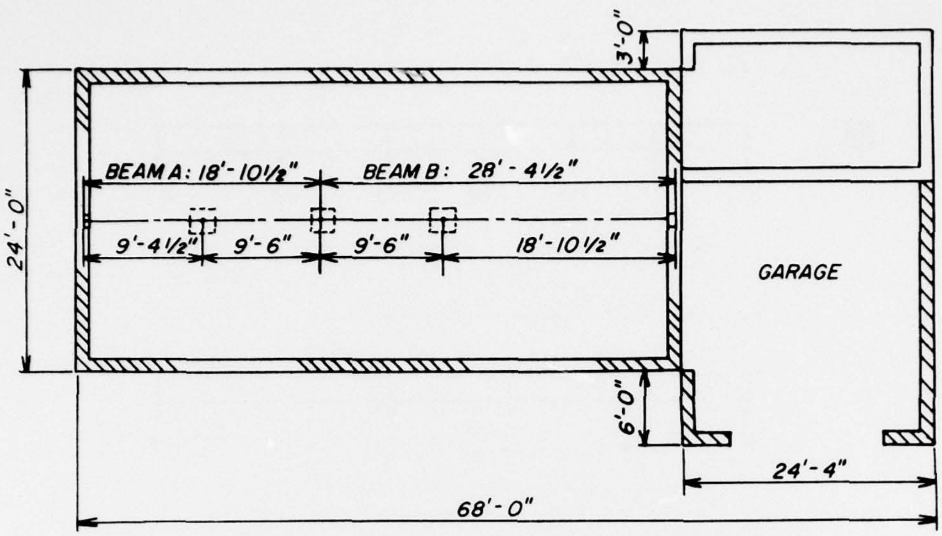

Figure 1.—Basement floor plan of test house.

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diate supports (fig. 2b). The Press-Lam beam was intended to provide an alternative to the steel beam when three intermediate supports are specified (fig. 2c).

Design Calculations

The final beam was designed to be 6 inches wide by 12 inches deep. Two sections were manufactured. Beam sections A and B (fig. 3) were field-spliced over a support with an array of nails. These nails provide little transfer of bending moment at small joint rotations. For this reason, the joint over the column at R3 (fig. 2) was considered to be nonrigid and was assumed to be a simple support for design purposes. However, a rigid structural joint was provided over the column adjacent to the longest span (R4, fig. 2) to minimize deflections on the long span. The final beam dimensions and lap-joint configuration are shown in figure 3.

An evaluation of the design strength and stiffness of the three beams shown in figure 2 is given in the appendix.

Verification of Lap-Joint Design

As noted, beam section B (fig. 3) was designed to be structurally continuous over one of the column supports, and assurance of the adequacy of the joint design was required. As outlined in the appendix, the joint was designed such that bending stresses in a ply, rather than the torsional shear stresses in the lap, would be critical.

A beam section 5½ inches wide by 10 inches deep by 9½ feet long with a lap joint at midspan was tested to examine its failure mode. It was loaded in center point bending on a 9-foot span. The specimen failed in a bending mode, similar to other Press-Lam members with butt joints. The MOR on the gross section was 3,150 psi, and the MOE was 2.0 x 10^6 psi. Assuming that the outer four plies (the last leg of the lap joint) cannot transmit bending stresses, the MOR on the net section becomes 4,200 psi. This value is 23 percent less than the mean strength of 5,450 psi found for the beams without a lap joint.

Even with this reduction in strength the joint exhibited nearly twice the required design strength and failed in a bending mode. Based on these considerations, the structural lap joint was considered adequate.

The measured MOE in this test also served to verify the hypothesis that butt or lap joints did not reduce the gross section bending stiffness.

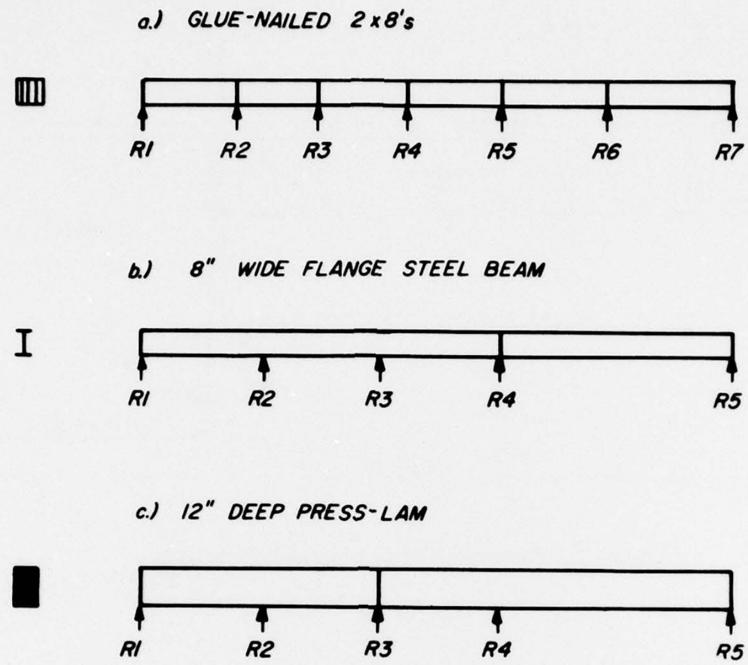

Figure 2.—Three typical basement beam designs.

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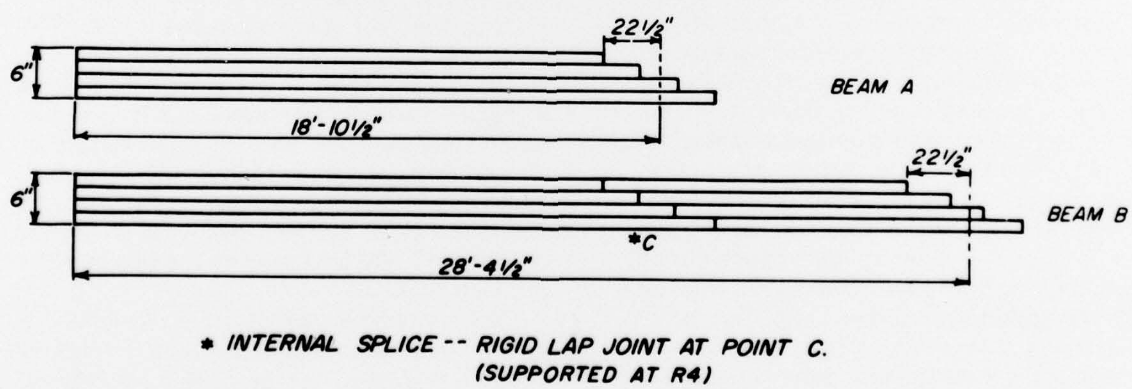

Figure 3.—Plan view of beam section dimensions and lap joint configuration.

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U.S. Forest Products Laboratory.

Design, performance, and installation of a basement beam in a factory-built house, by J. A. Youngquist, D. S. Gromala, R. W. Jokerst, R. C. Moody, and J. L. Tschernitz. Madison, Wis., FPL, 1978. 9 p. (USDA For. Res. Pap. FPL 316).

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Installation of Basement Beam

The beam was delivered in January, 1977, to the Wausau Homes plant in Wausau, Wis., in two sections—section A measuring 18 feet, 10½ inches; section B measuring 28 feet, 4½ inches. Each had one staggered end (fig. 3) to allow for the field splice.

At the erection site near Wausau, the two sections of the beam were removed from the truck and placed at ground level on the edge of the foundation. The sections were connected with an array of nails. The top course of the foundation served as a leveling device to align the splice. When the two pieces were joined, the finished beam measured a nominal 6 inches wide by 12 inches deep by 47 feet, 6½ inches long. A deflection line was installed on the beam at that time. The beam was then installed in precut pockets in the concrete block foundation (fig. 4). Steel shims were used to level the beam. Although the construction crew had had no prior experience with beams of this length, no erection problems were encountered.

As various housing components were assembled on the structure, beam deflection measurements were taken. With all of the exterior and interior walls in place, the floor panels secured, and the roof panels in place, no beam deflection was detectable. The owner's impressions of overall beam performance will be monitored periodically.

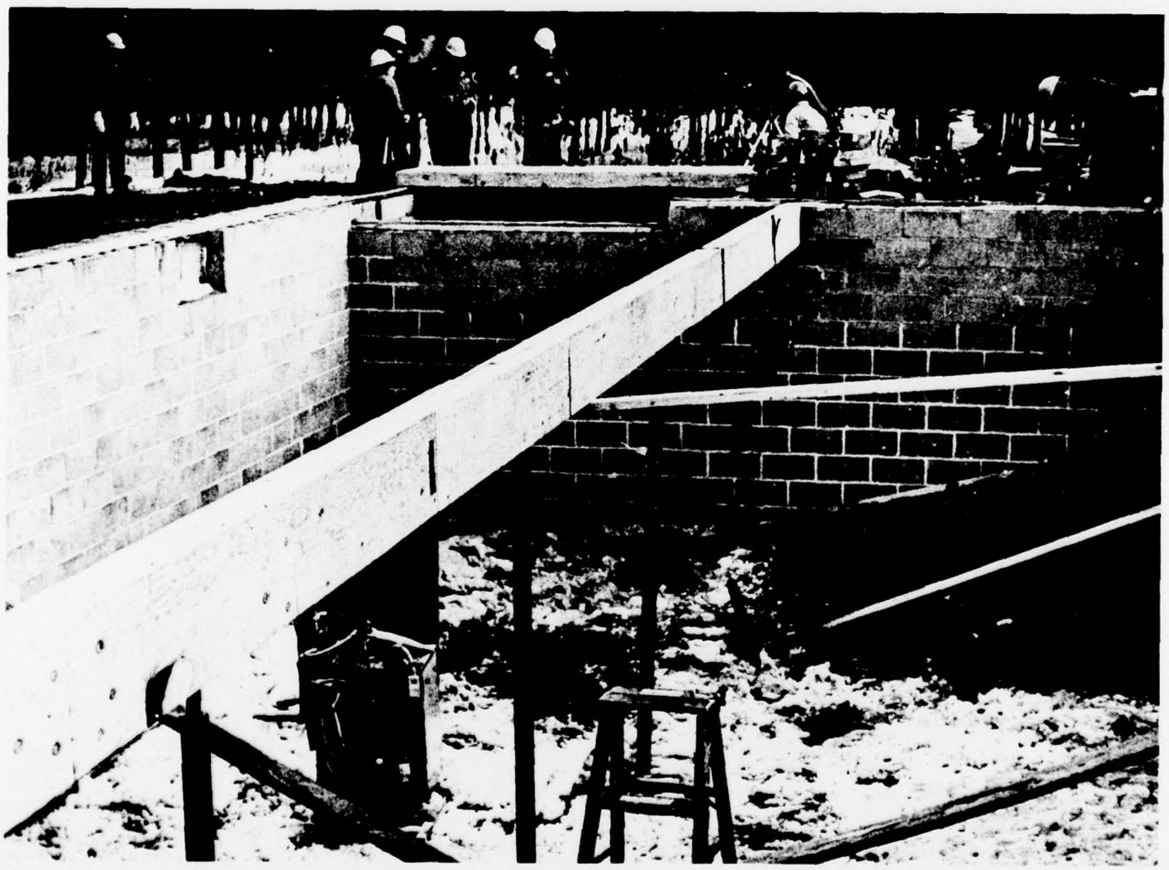

Figure 4.—Press-Lam beam installed in test house.

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Summary

A main basement beam, manufactured of Press-Lam, was designed for a specific loading configuration and installed as the main supporting member for a factory-built house. The beam was installed by the regular construction crew using no special equipment or techniques. The structural continuity of the Press-Lam beam provides greater effective span stiffness, resulting in a larger column-free basement area than is possible using the standard glue-nailed beams. In designs where the additional beam depth can be tolerated, Press-Lam can be used as an alternative to a steel beam.

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Appendix

Bending Stresses and Deflections

The design of this house was based on a 24-foot bay width (dimension perpendicular to the beam axis). Half of this width contributes load to the beam, while the rest is distributed between the foundation walls.

Thus, design loads convert to uniform distributed loads as follows:

Floor: 40 psf x 12 ft = 480 lb/linear ft, live
8 psf x 12 ft = 96 lb/linear ft, dead

Roof: 30 psf x 12 ft = 360 lb/linear ft, live
8 psf x 12 ft = 96 lb/linear ft, dead

The 18-foot, 10½-inch span nearest the garage is subject to floor loads only, as a ridge beam across the living room carries the roof load above this span. All other spans are beneath a load-bearing partition and carry both floor and roof loads.

NDS permits a 15 percent increase in nominal design stresses when designing for snow loads. The snow load is 35 percent of the total load for this design, thus it is the critical design case.

Analyses were performed on the three beam configurations with the following assumptions:

(a) Glue-nailed 2 by 8's:
Allowable bending stress = 1650 psi[4]
Increase for snow duration = 1.15 x 1650 = 1900 psi
Modulus of elasticity (MOE) = 1.7 million psi
All spans simply supported.

(b) 8-inch wide-flange steel beam:
Yield stress (f_y) = 36,000 psi
Allowable bending stress = 0.6 x f_y = 21,600 psi
MOE = 29 million psi.

(c) 12-inch-deep Press-Lam beam:
Allowable bending stress = 2330 psi
Increase for snow duration = 1.15 x 2330 = 2680 psi
MOE = 1.7 million psi.

Conventional engineering mechanics formulae were used to analyze the beams. Maximum bending stresses and deflections expressed as a fraction of the allowable are shown for the three design alternatives in figure A1. For each beam section, stresses and deflections shown are for the most critical loading combination.

Design of Lap Joint

The lap joint was designed such that the theoretical strength of a single glueline with an area of *b* (lap length) times *h* (beam depth) would transmit bending stresses equal to the moment capacity of a single leg of the joint (4 plies). These stresses are transmitted through torsional shear in the joint.

Both bending and torsional shear stresses are linear functions of the applied moment at the joint:

$$\sigma_{max} = \frac{M}{S};\ \tau_{max} = \frac{1}{\alpha}\frac{M}{6S} \qquad (1A)$$

where

σ_{max} = maximum bending stress (psi)
M_{max} = maximum bending moment (inch-pounds)
S = section modulus = $\frac{th^2}{6}$ (in.^{3})
t = beam width (in.)
h = beam depth (in.)
b = lap length (in.)
τ_{max} = maximum torsional shear stress (psi)
α = factor tabulated in mechanics text dependent upon joint geometry.

It was assumed that the ratio of bending strength to shear strength of this Press-Lam material is about 12 to 1, i.e.,

$$\sigma_{max} = 12\,\tau_{max} \qquad (2A)$$

[4] No. 2 Douglas-fir, repetitive use.

Then, substituting values of $\frac{I}{c}$ tabulated in mechanics of materials textbooks (e.g., *6*), and iterating yields

$$b_{min} = 15 \text{ in.} \tag{3A}$$

Assuming that one leg of the joint (4 plies) is ineffective in resisting bending stresses at the joint, the bending stress is

$$\sigma_{max} = \frac{M_{max}}{S} \frac{21{,}660 \text{ lb-ft}}{108 \text{ in.}^3} = 2{,}400 \text{ psi} \tag{4A}$$

This stress is less than the allowable value previously derived, and the lap length of 15 inches is adequate.

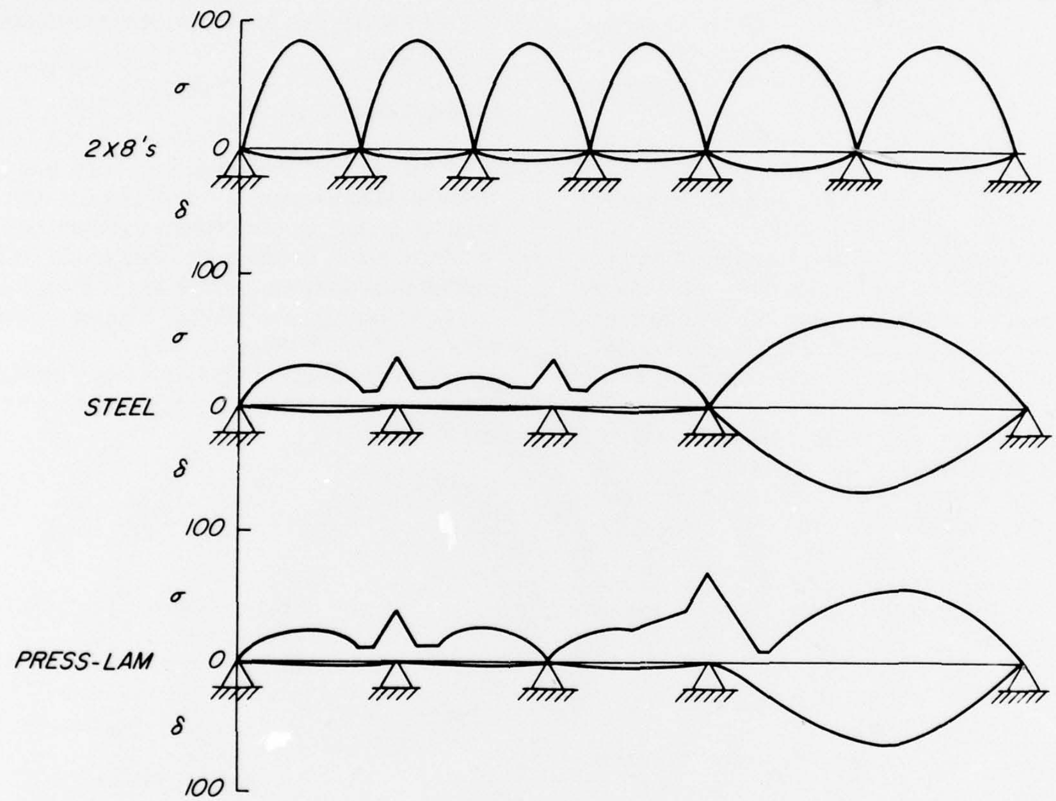

Figure A1.—Normalized stresses (σ) and deflections (δ) for 3 beam configurations expressed as a percentage of the allowable.

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